

Final Report

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An Engineering Analysis of Egg Processing
Wastewater Using a Physicochemical Treatment Process

by

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INTRODUCTION

This project focused on wastewater treatment in the egg processing industry utilizing a physicochemical process developed by the U.S.D.A. food laboratories. When first initiated this project involved the design, construction, and start-up of a pilot plant at the Colonial egg processing plant in Douglas, Georgia. After initial set up of a 30 gallon batch treatment system, the Colonial plant was forced to permanently shut down operations for economic reasons. This resulted in Georgia Tech changing the scope of the project, and spending the remainder of the project year working in the laboratory on engineering problems associated with the treatment system.

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BACKGROUND

In the State of Georgia in 1979 over \$335,000,000 was generated by the egg grading/processing industry. In Georgia this accounted for more than a third of all the revenue earned in the poultry industry.⁽¹⁾ Nationwide the egg processing industry exceeds all other poultry operations in revenue produced. In any food processing industry water is used to clean the product before it is safe for human distribution. Consequently the bulk of this water ends up as discharge from the plant.

Research reports indicate that about 3 to 6% of the shell eggs entering grading plants are broken during processing.^(2,3) In addition, they are often located in small rural communities and because their wastewaters although small in quantity (5,000 -10,000 gals/day) are highly contaminated (1,000 -10,000 mg/l BOD), they can put a severe burden on municipal treatment systems creating significant water quality degradation.

As part of the increased public environmental awareness, new laws have been instituted to control all point sources of industrial wastes. As these government restrictions on industrial wastewater discharges have increased since the Federal Water Pollution Act Amendments of 1972, more and more small industries have begun to experience the economic burdens in dealing with their waste streams. The egg grading/processing industry is typical of this group. For years egg processing

plants merely discharged their water into the municipal sewers in their respective communities and that was the end of their problem. However, with the upgrading of municipal sewer works in the last 10 years which were largely funded with federal monies, industrial cost sharing surcharges have arisen, placing a fine on those industries discharging waters above a standard BOD (biological oxygen demand) and SS (suspended solids) level. The result of this being a decision by the industry involved to either continually pay this surcharge rate or avoid paying by means of initiating a wastewater treatment program. This program can take one of three avenues. First, they may directly discharge to a receiving stream, but the restrictions on this procedure are far more prohibitive than municipal discharge. Second, they may install a pretreatment system and lower the BOD and SS of their discharged waters to meet municipal limits. Thirdly they may consider water reuse or no direct discharge by means of using land application.

PROCESSING SYSTEM

Independent of the plants size, it is not unusual that most plants' layout and mode of operation are nearly identical. Figure 1 shows a flow chart for an egg grading plant.

The initial step in the production process is receiving the flats of eggs from the egg farms. These eggs are stored in a cool humid climate to maintain egg freshness and minimize evaporation of water from the egg contents. Once these flats reach the washer the eggs are manually loaded onto a conveyor belt of rubber rollers. The responsibility of checking the eggs to remove any "leakers" (broken shell with contents exposed) rests with the loading operator. When a case of eggs has been loaded onto the washer, the empty flats area set aside to be returned to the egg distributors or bailed for sale as scrap paper. As the eggs move through the washer they are scrubbed by brushes moving in a vertical direction. Simultaneously warm water is pumped from the washer's holding tank and sprayed across the surface of the eggs. The washing tank contains between 50-80 gallons which is continually recycled for a four hour egg processing period, then dumped and refilled for the next shift. This water initially contains detergents and defoaming agents, but as it is continually recycled it picks up egg solids, egg shells and foreign material removed from the shell surface.

Once the eggs have passed through the scrub brushes they are rinsed with a warm chlorine spray containing 100-200 mg/l

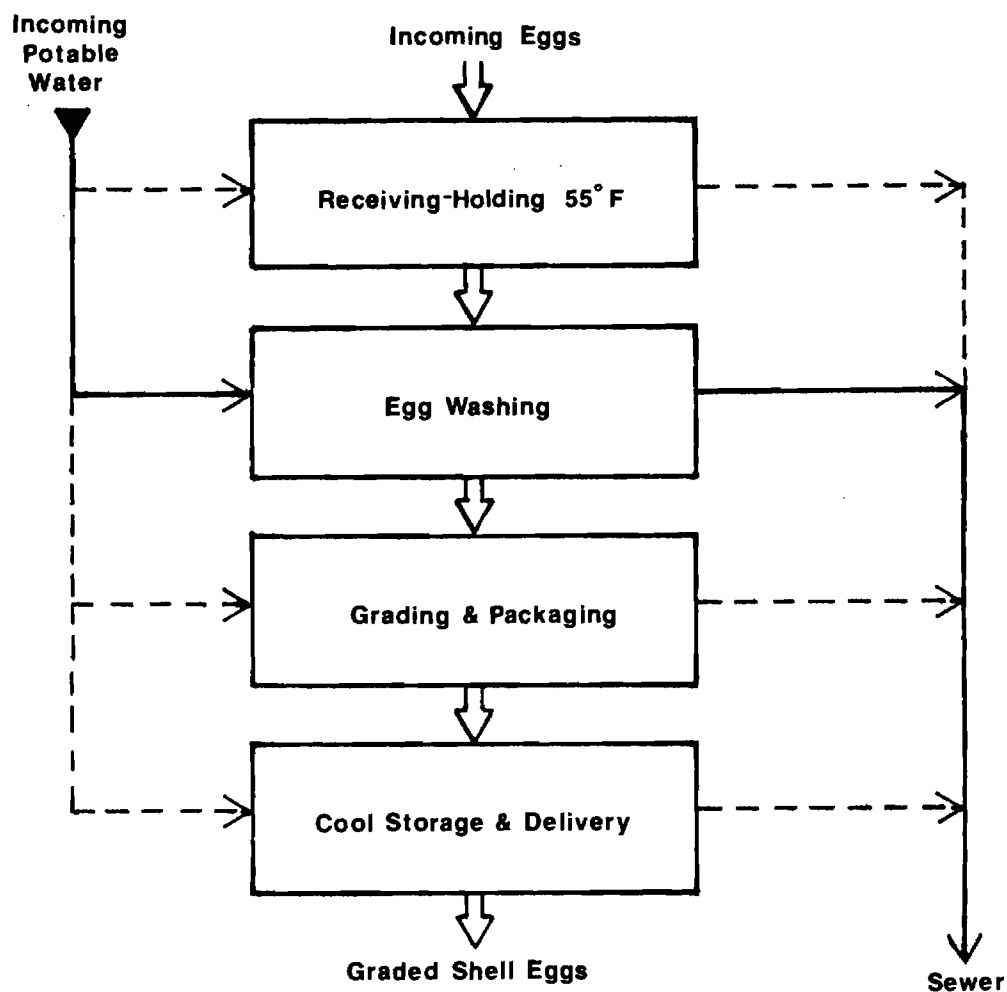


Figure 1.

Flow chart of commercial egg grading plant. The only processing area with a constant demand for water is the washer. Other areas use water for clean up more or less on an as-needed basis which may be once daily or much less infrequent as in the cool rooms. (Constant flows are indicated by a solid line in figure, intermittent flow by a broken line.)

chlorine. This rinse along with a spray rinse which preceeds the scrub brushes constitute a continuous overflow of water from the washer. Figure 2 shows a simplified egg washing machine. The eggs are then conveyed above a series of brilliant lights for inspection in a candling operation. At this point inspectors remove leakers, blood spot, broken shells from eggs whose contents have been lost to the washer and eggs of poor interior quality. These inedible eggs are collected in segregated large containers for pet food products. It is also at the candling location that dirty eggs are removed to be rewashed. From the candler the eggs are sorted into their different sizes, put in dozen containers and then transferred into 15 or 30 dozen cartons. Once cartoned the boxes are moved by conveyor to the finished egg cool storage room to wait for shipping.

Normal production is from 8-10 hours per day. At the end of the processing day egg washer contents are again dumped into the sewer and the cleanup process begins. There is a final complete and intensive washdown which results in a substantial amount of water and egg solids (lost to floor spillage) reaching the sewer.

Wastewater Characteristics

Typical egg processing wastewater flows are between 3000 gpd-9000 gpd, with large sewer surges every four hours due to wash water dumping cleanup at the end of the day. This water contains egg shell, liquid egg contents, dirt and manure, detergent, defoaming agents, and miscellaneous other foreign

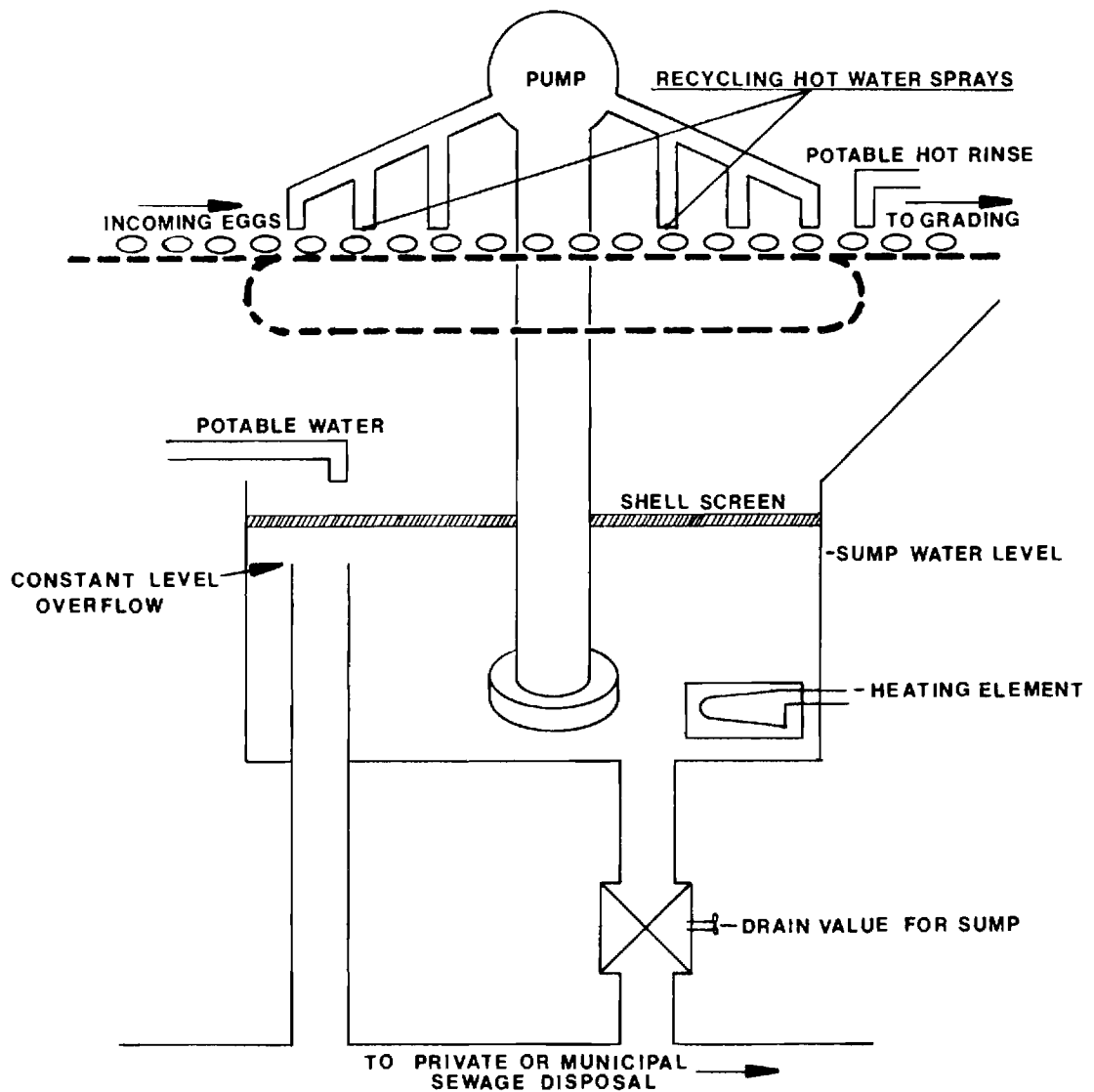


Figure 2.

Schematic of in-line egg washers. This represents only the minimum basic design. Washer systems may incorporate brushes along with the hot water spray and blower-dryers after the final rinse. All systems use a detergent in the wash water.

matter. The wastewater has a pH in the range of 10.0-10.5 from the highly alkaline detergents used. Hamm, et al ⁽⁴⁾ tested various egg grading plants and came up with the following parameter concentrations, Table 1. Bully, et al came up with average values for various parameters as shown in Table 2.

Treatment Alternatives

Studies of wastewater problems in egg processing and egg breaking plants ⁽⁵⁾ indicate that many facilities are presently experiencing difficulties in the treatment of their effluents. It might also be estimated that a portion of those that are not aware of the problem will experience difficulties in conforming to new federal and state regulations in the near future.

Jewel, et al have to date compiled the best study on egg processing and egg breaking wastewater treatment. They looked at four types of treatment systems: aerated lagoons, activated sludge, anaerobic lagoons and rotating biological contactors. ⁽⁵⁾

An aerated lagoon is a dilute, completely mixed unit operating without solids recycle. The lagoon is often an earthen lagoon with elevated banks to minimize water losses due to wave action caused by aeration units. ⁽⁶⁾ Oxygen is supplied to the lagoon by either diffused aerators, surface aerators or sprayed air turbine systems. Aerated lagoons have been successful in the treatment of a number of food processing wastes including peaches, peas, apples, and dairy. This treatment process has

Table 1. Wastewater Characterization of Egg Grading Plants

			2			
			Solids			
		COD	Fat ¹	Total (mg/l)	Residue	Volatile
Egg grading plant ⁴						
	High	26,300	3,840	26,700	14,080	12,630
Washer overflow	Median	7,200	1,290	9,970	3,440	4,830
	Low	1,200	130	1,910	1,260	650
	High	17,300	3,840	20,440	11,540	8,900
Washer Sump	Median	7,400	1,280	9,730	4,140	4,030
	Low	1,200	210	1,910	1,260	530

1 Hexane Extractables

2 Dry matter obtained by drying at 103° C. to constant weight;
residue=that remaining after firing at 600° C. for one hour.

3 By Micro-Kjehdahl method

4 Samples were drawn during full processing and represent only values
for that specific time.

Table 2. Typical Egg Grading and Processing Wastewater Characteristics

Analysis	Mg/l
BOD	6300
COD ⁵	9780
T.S.	6950
Kjeldahl-N	537
NH ₄ -N	48
NO ₃ -N	2
PO ₄ ³ -P	144

experienced widespread use because it requires little operational control. Biological equilibrium will be established with time and will adjust automatically to absorb various change in loads. The absence of the need for complex mechanical maintenance other than lubrication and periodic inspection also makes the aerated lagoon an attractive treatment process. Results of their work on aerated lagoons showed the following results, Table 3. The aerated lagoons were capable of reducing a total effluent COD ranging from 4000-10,000 mg/l to a soluble effluent COD less than 1000 mg/l at all three hydraulic retention periods (10, 20, 30 days), even though these results indicate that aerated lagoons are capable of soluble COD removal efficiencies greater than 90%, the quality of effluent is not good enough to satisfy effluent discharge requirements. The units also had a strong pungent odor for aerobic lagoons.

Table 3. Summary Aerated Lagoon Characteristics and Removal Efficiencies

Lagoon Characteristics						
Parameter	<u>Plant A</u>			<u>Plant B</u>		
	Hydraulic retention period, days					
	10	20	30	10	20	30
SS(mg/l)	1050	560	550	890	1,300	850
Oxygen uptake rate(mg/l/hr)		9.3	7.3	25.3	13.8	7.0
Removal effic.(%)						
COD, Total	59.8	72.3	81.1	69.2	66.1	76.5
COD, Soluble	89.7	88.3	96.2	86.9	93.7	94.3
TKN, Total	64.2	41.2	64.9	51.1	49.8	58.7

It should be anticipated that treatment of egg processing wastewater with the activated sludge process will be difficult because of the high strength of the wastes. Effluent quality results from the above research⁽⁵⁾ were similar to those of the aerated lagoon. The sludge produced in these units settled poorly and the high effluent turbidities indicated that this process would be a poor choice for the treatment of egg processing or egg breaking wastes. The activated sludge process was capable of producing an effluent suitable for discharge to a joint treatment system without resulting in a surcharge for excessive oxygen demand or suspended solids. However, problems with settleability of the sludge should be anticipated with this system.

The final aerobic treatment process investigated in the literature was the rotating biological contactor (RBC). The previous treatment schemes above, involved suspended growth systems whereas the RBC is an adhered growth treatment unit. This system is similar to the previous processes in that excess solids are produced by the oxidation of the substrate and have to be removed from the effluent. The results from the RBC treatment at a hydraulic retention period of nearly two days were very promising. Regardless of the loading rates used (#COD/ft²) there was always a dissolved oxygen level in the RBC unit. The pH of the system remained between 7.2-7.7 and nitrification was higher than 50% efficient. The RBC units are capable of producing effluents suitable for further treatment without surcharge payments to municipalities and low loading rates can produce

effluents with low turbidities. The question that must be answered for a particular egg processing plant is whether the capital cost for equipment and operating cost for power, maintenance and sludge handling are less than surcharges encountered if no treatment were applied.

When anaerobic lagoons are mentioned most people think of obnoxious odors, namely hydrogen sulfide or "rotten egg" odors. Contrary to this assumption, anaerobic lagoons properly maintained do not produce highly objectional odors when treating egg processing wastewater. However anaerobic lagoons by themselves would not be acceptable because of the oxygen demand associated with the discharge of wastes from anaerobic processes. Thus all anaerobic lagoons should be followed in series with aerobic lagoons operating at a six day detention period. Anaerobic-aerobic lagoon systems have operated with COD removal efficiencies between 80-91%. But perhaps the most impressive characteristics of the combination lagoon system is the high clarity and high flocculated nature of suspended materials in the effluent from the aerated unit. Since all solids settled rapidly BOD values of less than 10 mg/l are indicative of the efficiency that this treatment combination is capable of achieving with an influent COD varying between 5,000-10,000 mg/l.

EXPERIMENTAL PROCEDURE

Samples of wastewater were taken from an egg-washing machine in a commercial egg processing plant. The samples were collected in a 10-gallon plastic container from the recycle line just before the contents were scheduled to be dumped. The samples were stored at 4°C within 2 hours of collection and used in treatment studies within one week.

Biochemical oxygen demand (BOD) was determined according to Standard Methods (1975) using a dissolved oxygen meter (Yellow Springs Instrument Co.) Chemical oxygen demand (COD) was determined by the micro ampule method (Oceanographic International). Total, suspended and dissolved solids were determined by evaporating a sample to a constant weight at 105°C. Volatile matter was determined by firing the samples at 600°C as per Standard Methods.

RESULTS and DISCUSSION

The treatment system Georgia Tech has been experimenting with was developed in the laboratory by Drs. W.A. Moats and C.E. Harris, food chemists with the U.S. Department of Agriculture. Their system for treating egg wastewater has been successful in reducing BOD on a laboratory scale.

This system relies on physical-chemical treatment as opposed to biological decomposition of the wastewater. The highly alkaline egg wash water is first acidified to pH 4.7 by sulfuric acid addition. It is then heated to a range of 160-170°F for one-half hour, with continuous stirring. At this point coagulation of the dissolved egg albumen takes place and a fine pin point floc begins to develop. Afterwards heating and stirring are ceased and the quiescent mixture is allowed to cool.

Hamm, et al reported that water from egg washers in egg-grading plants had a median chemical oxygen demand (COD) of 7,300 mg/l with a range of 1,200 to 26,300 mg/l.⁽⁴⁾ The values agree well with the COD for the samples we collected from the egg-washer. Moats and Harris reported a 76 to 97% reduction in the COD of the wastewater using their process. Table 4 shows the COD and BOD concentrations before and after treatment that were obtained during our experiments. The lower COD removals (37 to 86%) obtained during our tests probably resulted from using a different solids separation technique and from the lower initial waste concentrations. After treatment, Moats and Harris used a

centrifuge to separate out the solids while we sampled the supernate after five hours of gravity settling. Also, the efficiency of the process is seen to be directly related to the initial concentration of the wastewater with the efficiency increasing with higher concentrations.

Table 4. Results of Treatment of Egg-washer Water by Acidification to pH 4.7 and heating to 75°C. After Treatment Samples taken from Supernate after 5 Hours Settling.

Sample	COD		% Reduction
	Before	After	
A	3760	520	86
B	600	380	37
C	1080	640	40
D	3620	600	83

	BOD		% Reduction
	Before	After	
E	1290	153	88
F	1150	150	87
G	800	330	59

The wastewater from the egg washers is rather alkaline with a pH of about 10. A precipitate is produced when the pH is lowered by the addition of acid. An optimum precipitate is produced at pH 4.7 and lower pH values tended to redissolve some of the floc. The reaction of the pH of the wastewater to the addition of 1N sulfuric acid is shown in Figure 3. From the titration curve one can calculate the volume of sulfuric acid required to lower the pH of the wastewater.

A considerable amount of precipitate is formed after adjusting the pH to 4.7 but the supernate remained quite turbid.

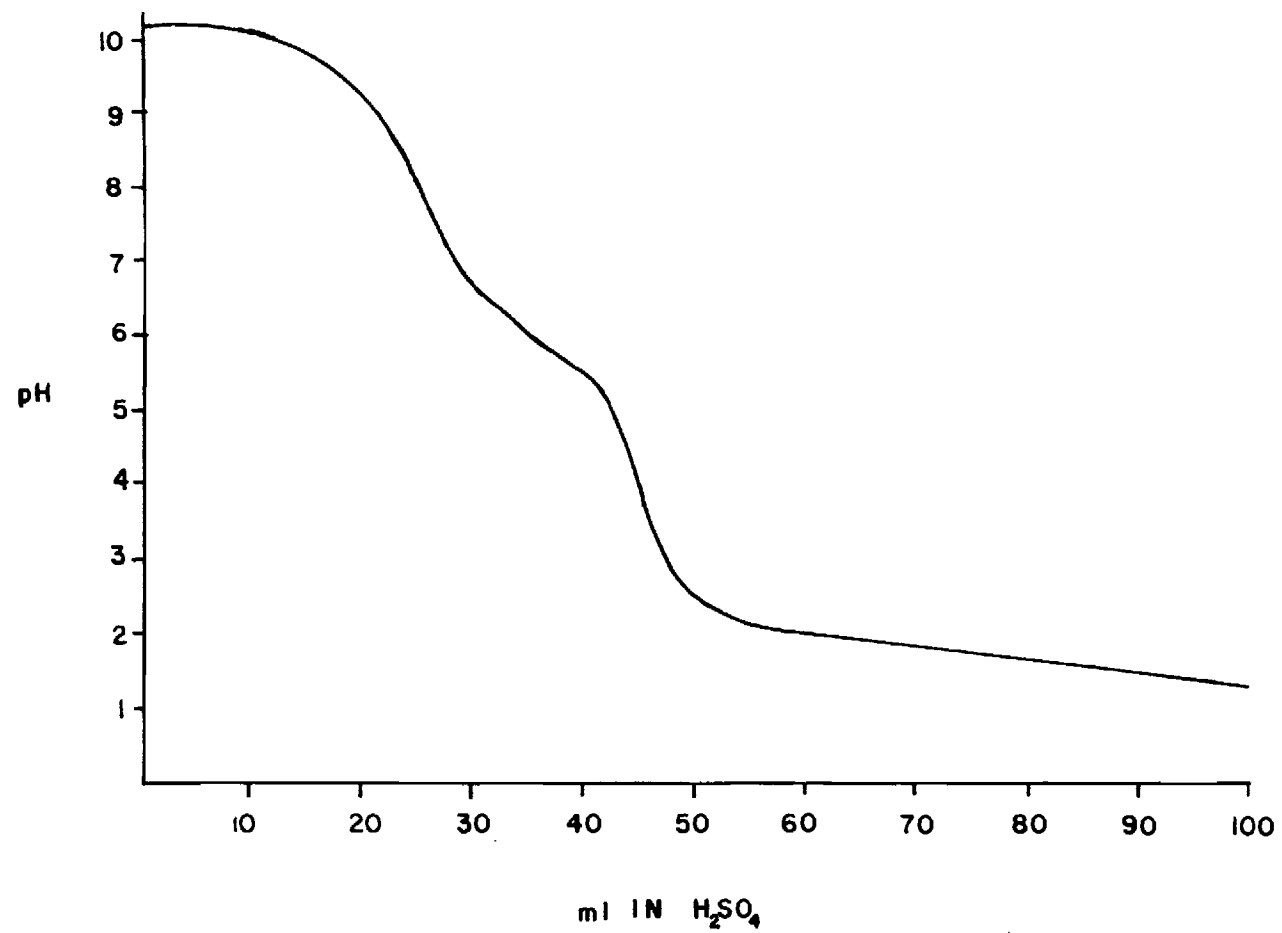


Figure 3

Reaction of the pH of Egg Wash Water to the
Acidification of 1N Sulfuric Acid

Additional precipitate is formed when the mixture is heated and after settling, a relatively clear supernatant is left. Table 5 and 6 show how the treatment results in an increase in the suspended solids and a decrease in the dissolved COD.

Table 5. Suspended Solids Before and After Treatment.

	Suspended Solids (mg/l)
Untreated	600
Treated*	3,380

*pH adjusted to 4.7 and heated to 70°C for 30 minutes.

Table 6. COD Reduction Resulting from Treating Egg Waste Water with Acid to pH 4.7 and Heating to 70°C.

	COD (mg/l)	% Reduction
Untreated (total)	4,500	
Untreated (dissolved)	2,800	
Treated* (dissolved)	600	87%
Treated (supernatant)	610	86%

Problems with solids separation were encountered when trying to scale up this process to a pilot plant operation using gravity separation. In the lab experiments conducted by Moats and Harris, separation of the floc from the water was accomplished by centrifuging samples for 10 minutes at 5,000 rpm. The high costs (initial investment, operation and maintenance) associated with

centrifuging on a full scale would render the process economically unfeasible. So simpler, less expensive techniques were evaluated.

Gravity settling proved to be very slow and unreliable. No settling would occur until the temperature of the treated wastewater would approach ambient temperature. Minor convection currents resulting from temperature differences were sufficient to prevent the floc from settling. The specific gravity of the floc was so close to that of water, that its behavior was unpredictable, sometimes it would settle, float or remain suspended. A batch treatment system utilizing a 30 gallon complete mix conical tank was fabricated and installed in the processing plant. Optimum settling time was established from 2.5-3.0 hours. Removing the settled sludge layer by means of pumping caused an immediate shearing of the sludge particles and consequently a resuspension of the wastewater mixture. When the floc did settle it would be resuspended by the slightest agitation, such as attempting to draw off the supernatant.

Jar tests were then conducted with various polymers to see if they could improve the properties of the floc. Table 7 lists the polymers that were tried. Drewfloc 2270 produced the best results. With the addition of this polymer the floc tended to clump together and become somewhat tougher. The addition of the polymer was tried in all of the following solids separation tests.

Table 7.

Cyanamid Co.

Magnifloc	1820A
	1839A
	507C
	572C
	581C
	2535C

Drew Chemical Co.

Drewfloc	495
	260
	280
	270
	2270
	1
Amerfloc	10
	490
Amersep	618

Calgon Chemical Co.

L650E
L670E
L690E
L635E
Cat-Floc
Cat-Floc T
WT 2635
WT 2640
WT 2575

The feasibility of filtration as a process for removing the coagulated egg solids was evaluated by using a filter leaf test apparatus. Various filter fabrics were tested but all failed to perform satisfactorily. In most cases the floc would shear and pass through the filter. When any solids were retained on the filter they would cause the filter to blind, making it very difficult to continue the test. In addition a sludge bag system was evaluated. This system utilized polypropylene filter cloth manu-

factured in a "sock" configuration at two porosity sizes: the first at 30 cfm and the second at 12 cfm. Neither of these tests was successful, and since lower porosity cloths are not manufactured, further testing was not possible. It was hoped that the treated wastewater could be pumped into the socks and then due to its slow filtration rates through the cloth, the wastewater would have enough time to allow for coagulation of the floc. However shearing of the floc continued with the porosities mentioned above.

Dissolved air floatation (DAF) is another operation used to separate solids from a liquid phase. In this system air is dissolved in the wastewater under a pressure of several atmospheres, followed by release of the pressure to atmospheric level. When the pressure is released air comes out of solution and forms small bubbles which rise to the surface carrying particles with them. A bench scale DAF unit was used to evaluate its usefulness in treating egg wastewater. A 20 liter pressure vessel was charged with 10 liters of treated wastewater. The contents were pressurized at pressures of 30, 40, 50 and 60 psi. The detention time was varied in five minute increments from 5 to 30 minutes. In some trials the contents were mixed while under pressure to enhance the dissolution of air into the water. In all cases the DAF failed to separate the solids from the liquid. It appeared as if the handling involved in using the DAF process tended to emulsify the floc so that it could not be separated successfully.

CONCLUSIONS and RECOMMENDATIONS

The physicochemical treatment process for egg wastewater, developed in the laboratory by Drs. Moats and Harris, has a significant solid-liquid separation problem when scaled up for commercial application. This is due to the fragile nature of the flocculated egg albumen particles which result from acidification and heating of the wastewater. Polymer addition to the chemical process does little to toughen the floc. The most cost effective physicochemical treatment process would utilize a batch system whereby solid-liquid separation could be carried out using a conical tank for gravity settling. Since pumping of the settled sludge blanket is not possible due to floc shearing, manual drawoff of the supernatant would be required. Drawoff would continue until the level became low enough to start causing disturbances with the sludge blanket. Using a conical tank with a large height to diameter ratio, the amount of clear supernatant drawn off could be maximized, in the range of 70-80% of the original wastewater volume. The remaining 20-30% of treated wastewater and sludge (settled floc) could then be pumped onto sand drying beds. This type of batch system would be relatively inexpensive, and since less than a third of the original wastewater need be left for eventual evaporation-percolation, a minimum amount of land would be required for sand drying beds.

In addition to the actual treatment system discussed above, certain procedures should be followed by egg processing plant managers to lower plant effluent concentrations.

1. minimize use of improper stacking of eggs in storage, or weak storage boxes.
2. minimize number of times eggs are handled and length of the conveyor system.
3. frequent adjustment of brushes in washers to minimize breakage.
4. efficient collection of discarded eggs.
5. maximize dry cleanup of plant at end of day.

In addition to these steps Georgia Tech has found that an integrated system to conserve water usage in the processing plant is also needed. The two areas where significant water savings can be earned is in the cleanup process and in the egg rinsing spray. Far too much water is used in washing down plant equipment and floors at the end of the working day. The possibility of a wet vacuum system for cleaning floors should be looked into. This would not only reduce water consumption but also eliminate egg waste from entering the sewer discharge.

The egg rinsing systems around the plant should be checked to make sure that the minimum amount of spray nozzles, to adequately rinse each egg, are being used. Too often more spray nozzles than necessary are used, actually causing a reduction in overall spray effectiveness. Also, water pressure in the spray lines should not be above the manufacturers recommendations. With the implementation of these water conserving techniques on their egg spray rinses Colonial Egg Processors was able to cut down their consumption by over 5% and improve the quality of their final product as well.

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